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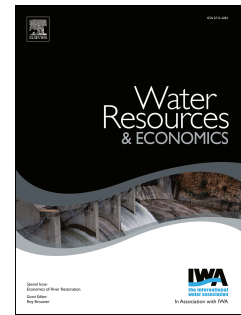
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# COVID-19 and Handwashing: Implications for Water Use in Sub-Saharan Africa

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## Abstract

Because the main modes of transmission of the COVID-19 virus are respiration and contact, WHO recommends frequent washing of hands with soap under running water for at least 20 seconds. This article investigates how the level of concern about COVID-19 affects the likelihood of washing hands frequently in sub-Saharan Africa. We discuss the implication of the findings for water-scarce environment. The study makes use of a unique survey dataset from 12 sub-Saharan African countries collected in April 2020 (first round) and May 2020 (second round) and employs an extended ordered probit model with endogenous covariate. The results show that the level of concern about the spread of the virus increases the likelihood of washing hands with soap under running water for a minimum of 20 seconds at least five times a day. The increase in the probability of handwashing due to concern about COVID-19, ranges from 3% for Benin to 6.3% for South Africa. The results also show heterogeneous effects across gender- and age-groups, locality and various water sources. However, in Africa, the sustainability of the handwashing protocol could be threatened by the severe water scarcity that exists in the region. To sustain frequent handwashing, sub-Saharan Africa needs an effective strategy for water management and supply.

**Keywords:** Covid-19; Handwashing; Water use; Sub-Saharan Africa

JEL: I18, Q25

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## 1. Introduction

In December 2019, the city of Wuhan, in China, recorded cases of COVID-19 caused by the SARS-COV-2 virus. By January 30, 2020, the World Health Organisation (WHO) declared a virus pandemic of international concern [1]. Since its identification in Wuhan, the virus has spread across all continents of the world, affecting more than 180 countries. In the beginning of March 2020, the total active cases stood at 109,000 with 3,800 deaths [2]. As of September 12 2021, the total cumulative confirmed COVID-19 cases is over 220 million and 4.5 million deaths globally [3]. Developed economies in Europe, North America, and Asia have been hard hit by the pandemic. Even though Africa might still not have seen its greatest impact, already there are predictions about the possible increase in the fatality rate on the continent due to its weak social and economic infrastructure base. The global spread of the novel COVID-19 virus has negatively affected many health systems around the globe, even the most robust ones. In addition, extended restrictions on movement and other lockdowns did trigger major social and economic crises [4]. Many economies around the world reported negative economic growth due to the adverse impact of the pandemic on production, distribution and consumption. According to World Bank data<sup>1</sup>, the global economy in the year 2020 grew by -3.5%.

The two main routes for the transmission of COVID-19 are respiration and personal contact. Measures recommended to contain human-to-human transmission include isolation, quarantine, social distancing and community containment [5]. According to Maier and Brockmann [6], these measures have proven to be effective in containing the spread of the virus in South Korea and China. In addition, the WHO & UNICEF [7] have recommended some basic measures to help reduce the spread of COVID-19. They include frequent washing of hands for at least 20 seconds using water and soap. Handwashing is effective in curbing infectious diseases. For instance, Jefferson et al. [8, 9] found that handwashing reduced transmission of respiratory viruses by 45-55%. For H1N1 influenza, Saunders-Hastings et al. [10] found that handwashing reduced transmission in human populations by 38%. Smith et al. [11] showed that handwashing effectively reduced transmission of influenza among adults. According to the WHO & UNICEF [7], providing water, sanitation and hygiene (WASH) are crucial to protecting human health from all forms of infections, including COVID-19. The WHO estimates that, before COVID-19, lack of access to safe drinking water and adequate sanitation hygiene increased the global incidence of disease burden by about 10%. In urban areas, the estimate showed that the return in saved medical costs and increased productivity for every US\$1 investment in basic sanitation is US\$2.5 [7]. The

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<sup>1</sup> <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG>

amount saved for rural areas for similar investment in sanitation is US\$5. Mattioli et al. [12] reported that the quantity of water used is associated with less viral contamination of hands. Hoque [13] estimates that 0.5 to 2 litres of daily water per person enable reduction of faecal contamination.

The above suggests that applying robust and consistent WASH programmes could effectively help contain the spread of the virus. However, while the washing of hands might be considered a routine gesture in developed economies with proper water resource infrastructure, for developing economies, such as Africa, it might be a luxurious endeavour. In Africa, a significant number of people do not have access to handwashing facilities. In sub-Saharan Africa, about 258 million people lack access to handwashing facilities (UNICEF & WHO Joint Monitoring Programme Reports). Figure 1 shows the plot of the coverage of people without access to handwashing facilities. It is clear from the figure that Middle, Western and Eastern African regions have the lowest levels of handwashing facilities in the world.

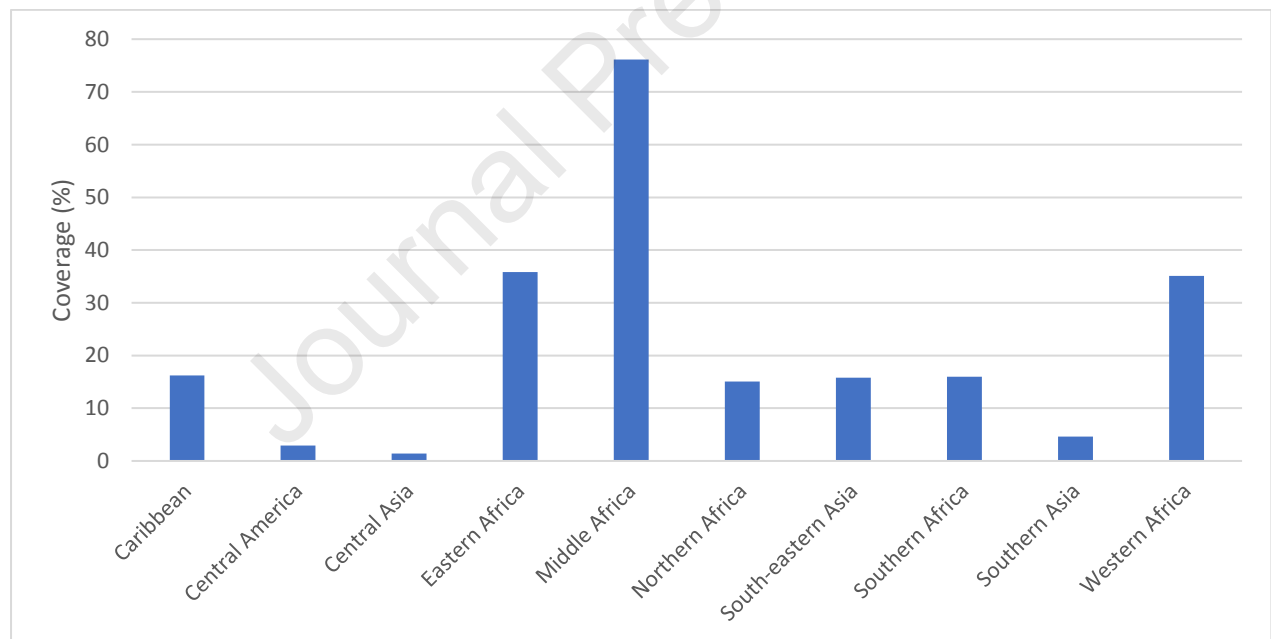


Figure 1: Percentage of people without handwashing facility, 2017

Source: Data from WHO & UNICEF Joint Monitoring Programme Report

One of the primary reasons is that the region has acute water shortage problems. As Baye [14] noted for Ethiopia, the suboptimal level of access to water and soap makes adopting the recommended handwashing action difficult, especially in rural areas. Equally important to the above discussion is the role of the concern of COVID-19 in handwashing behaviours. As cases of COVID-19 rise, we expect that greater concerns would be generated among people, and this could induce behaviour changes that includes the washing of hands. However, there is limited economic

analysis of how the level of concern about infectious disease, conditioned on other socio-demographic factors, affects the frequency of handwashing. More specifically, it is yet to be known how the level of concern generated from the spread of the novel virus affects the number of times a person washes hands. This is a critical question, especially in sub-Saharan Africa, where there is acute water shortage problem. The findings from such study have important implications not just on controlling/managing the current COVID-19 and other existing diseases such as cholera, but also preventing other future pandemics that may require water use as one of the treatment mechanisms. The aim of this article is to fill this gap by modeling the frequency of handwashing as a function of the level of concern about the novel COVID-19 in Africa.

This study is based on survey data from 12 Sub-Saharan African countries, collected between April 2<sup>nd</sup> and April 9<sup>th</sup>, 2020 (first-round data collection), and from April 24<sup>th</sup> to May 8<sup>th</sup> 2020 (second-round data collection) by GeoPoll. A simple random sampling technique was used by GeoPoll to select respondents from their database, which consists of a list of mobile subscribers in each country surveyed. We employed an extended ordered probit model with an endogenous covariate to address the potential endogeneity associated with concern about COVID-19. Principal component analysis was used to compute composite indexes based on the individual's sources of information about COVID-19, to serve as an instrument for the level of concern about COVID-19. We controlled for the effects of age, gender, water sources and residential type.

The results show that the level of concern about the spread of COVID-19 significantly increases the frequency of handwashing with soap under running water for at least 20 seconds. We also observed heterogeneities of the effect of level of concern about the spread of COVID-19 on frequency of handwashing across gender, age group, water sources and the selected sub-Saharan African countries. Given the existing lack of access to potable water and handwashing stations with soap and water in this region, and the projected spread and persistence of COVID-19, our findings generate the need for concern and policy action about water resource provision and management in the region.

The rest of the study is organised as follows. Section 2 reviews the relevant theoretical and empirical literature. Section 3 discusses the method and data. Section 4 presents the main findings with a discussion, and section 5 concludes with some policy recommendations.

## 2. Theoretical and empirical literature

Handwashing is a simple yet effective way to prevent the spread of infections and diseases [15, 16]. The Health Belief Model [17], the Theory of Reasoned Action [18] and the Theory of Planned Behavior [19] and its extensions [20] underpin most handwashing studies. The Theory of Planned Behavior (TPB) is the most widely used theoretical framework amongst these theories [20, 21, 22, 23, 24, 25]. TPB suggests that intention, which can be influenced by attitudes, subjective norms and perceived behavioral controls, is a significant driver of behaviour. Based on this theory, handwashing practices are assumed to be driven by the following: positive or negative evaluations, social pressures, and the individual's assessment of the level of ease or difficulty [26].

Several studies on handwashing have adopted TPB by focusing only on the behavioural aspects of hand hygiene. For instance, Mackert et al. [16] adopted TPB to design a campaign aimed at increasing handwashing behaviours among university students. Their results show that, although students' behaviour towards handwashing did not change due to the campaign, more students (12%) did use soap. Kitsanapun and Yamarat [27] also adopted TPB to assess handwashing behaviours among public health students. The authors show that, while attitudes towards handwashing are generally favourably high among public health students, they usually do not adhere to prescribed handwashing protocols. Other notable studies that have relied on the TPB framework include White et al. [26] and Reyes Fernandez et al. [28].

In Sub-Saharan Africa, Seimetz et al. [29] adopted TPB to examine school handwashing programs in rural Burundi and Zimbabwe. They show that, for both countries, self-efficacy and social norms were the most effective in changing handwashing behaviours. Similarly, Curtis et al. [30] reviewed planned, motivated and habitual hygiene behaviours in eleven countries, including six African countries (Ghana, Kenya, Tanzania, Uganda and Madagascar). Their results show that, whereas education at an early age influences improved handwashing behaviours, fear of diseases did not exist, except for occasional outbreaks of epidemics like cholera.

While behavioural factors may limit handwashing practices, water scarcity, a common characteristic of many developing countries, continues to contribute to the low levels of hand hygiene behaviours [14]. In a cross-sectional study conducted in Uganda, Atuyambe, Edia, and Orach [31] observed that water and soap were not usually available at handwashing facilities and therefore negatively impacted handwashing practices. Sheth et al. [32], in a clinic-based study targeted at pregnant women in Malawi, demonstrate that participants in a water treatment



intervention program are more likely to improve the quality of water use and additionally demonstrate better handwashing practices. Duse, Da Silva and Zietsman [33] examine coping hygiene practices in South Africa, a water-scarce country. Results show that, although there is a need for government to expand the provision of water resources, education is vital for the promotion of food handling and handwashing practices. Pengpid and Peltzer [34] reviewed hygiene behaviours in African countries. They concluded that knowledge and hygiene practices in African communities and healthcare settings are low, which they attributed to the availability of resources, such as water and soap.

These studies go on to suggest that, in less developed countries, where poor health care systems, high population densities, poor sanitation, and water scarcity are the norm, a simple act of handwashing proven to limit the transmission and contraction of COVID-19 could be a challenge. On this note, an important issue worthy of discussion is the effect of the concern of pandemic (i.e. COVID-19) on handwashing practices. The aim of this study is to provide an economic analysis of the effect of concern of COVID-19 (conditioned on socio-demographic characteristics) on handwashing practices in Africa.

### ***Concern for illness and handwashing***

Until the outbreak of the COVID-19 pandemic, simple preventive practices like handwashing was not given much attention in combating illness and diseases. The current literature on concern for illness and diseases, and the role of handwashing tend to focus on raising awareness about the pandemic and reduce the spread of the infectious disease.

Shook et al. [35] looked at the application of the behavioural immune system as distinct from the physiological immune system and how it can be used to create awareness and increase behaviours necessary to avoid diseases and illnesses. They noted that the behavioural immune system tends to differ among individuals and sought to find out if these differences were associated with their concern for the pandemic and their willingness to adhere to the COVID-19 protocols. A national sample of 1,019 Americans was used in a regression analysis framework. Controlling for factors such as the health history, political orientation, religiosity and demographics of the participants, Shook et al. [35] found their germ aversion and pathogen disgust sensitivity (the two measures of the behavioural immune system) to be associated with their concern for COVID-19 and willingness to engage in disease prevention behaviours. Individuals who are younger, more educated, recovered from COVID-19, more religious and those with higher income were more

willing to frequently adhere to the COVID-19 safety protocols. The study recommends that adverts about COVID-19 must induce a feeling of disgust to encourage individuals to adhere to protocols such as handwashing, social distancing and the wearing of facemasks.

In the Kurdistan region of Iraq, Zangana et al. [36] examined the factors that determine handwashing behaviors among internally displaced women. The study noted that diarrhea is a common killer among individuals displaced by conflicts and discusses how frequent handwashing with soap can drastically reduce or eradicate the problem associated with the disease. The study used two camps in the Kurdistan region of Iraq as the case study and employed the Barrier Analysis standard tabulation sheet to achieve its objectives. In all, 45 doers (those who handwash) and 45 non-doers (those who do not handwash) were used for the study. Results showed that no significant difference was observed between doers and non-doers in terms of factors such as self and action efficacy and the level of access to soap and water. The study also revealed that non-doers don't handwash because they find it hard to remember and they perceive the vulnerability and severity of the disease less. The study recommends that handwashing must be made convenient especially for non-doers to encourage them to do so.

Rahman et al. [37] also examined personal hygiene among University students of Dhaka, Bangladesh. Their study sought to know if the COVID-19 pandemic had illicit changes in their practice of hygiene. A total of 240 students were selected from different universities within Bangladesh. Findings show that about 40 percent of respondents practiced frequent handwashing while 60 percent of respondents have random durations of hand washing. It was also revealed how COVID-19 pandemic impacted their hygiene practices and adherence to the recommended protocols. In assessing hand hygiene compliance among students of health education, Onoigboria et al. [38] used 200 health education students of the Ambrose Alli University in Nigeria. They revealed a high level of compliance to hand hygiene among students of health education but no significant difference was observed between compliance of male and female students. To improve hand hygiene among students, their study recommends a multifaceted approach at both individual and faculty levels. According to Thorpe et al. [39], handwashing behaviour of individuals is associated with individuals disgust sensitivity which is linked to health anxiety of individuals and their compulsion levels to wash their hands.

***Water pricing, use, and financial sustainability.***

Water use, pricing and cost recovery have been major concerns for providers. Shen and Wu [40] reviewed the reforms in the pricing of water in China. Their study noted that while a comprehensive policy has been developed for the reform, its execution tends to deviate based on environmental, social and economic considerations. In Ghana and most developing countries, access to safe drinking water for individuals in most rural areas is a luxury. A good number of individuals rely on unclean sources of water for drinking and other domestic activities. Agyapong et al. [41] looked at how financially sustainable water systems can be provided for these deprived communities and the best way to recover the cost of these infrastructures. The study noted that proper skills in managing the systems' finances will be important for prudent use of generated revenues, conducting frequent maintenance of the system, and productivity improvement.

More recently, Massarutto [42] discussed the interconnections among water pricing, supply of water, and sanitation. The study recognized the pricing of water as a pivot in addressing economic and social issues such as efficient allocation of water resources, appraisal of financial investments, and the safeguarding of the rights of individuals. Although efficient water pricing will not solve all economic and social problems, the study acknowledged that policymakers can use it to solve many issues regarding water resources, especially their sustainability. Garcia-Lopez and Montano [43] also assessed the tariffs of households in Spain focusing on factors that explain the consumption of water by households and the differences across different regions. They show that prices tend to be high where the water resource is relatively scarce and low when it is readily available. This is consistent with the economic theory of supply as the availability of the water resource influences the cost and the consequent prices. The study recommends that policies must target the balancing of prices across the regions. García-López et. al., [44] also confirms these results.

The current rate of water consumption suggests that water resource may be a scarce commodity in the future if relevant authorities fail to take action. Efforts must gear towards protecting the resource and popularizing its prudent use. This will ensure an appropriate attitude from users and management and lead to the conservation of the resource. Sanabria and Torres [45] introduced a framework that connects the valuation of the resource cost and the sustainability of the environment to promote efficient use of water and ensure that posterity does not suffer from water scarcity. To capture the uncertainty that surrounds sustaining the environment and its resources, the study recommended the use of stochastic models. Pinto et al. [46] also investigated the negative effect of climate change on the delivery of utilities such as water. It emphasized the

recurrent scarcity of water as one of the many consequences of climate change on the environment. This problem is fueled by factors such as inadequate infrastructure and the fact that resources are contaminated and over-exploited. The study further mentioned that an adequate supply of water will depend on the level of readiness with regards to important aspects such as demand for water, its pricing, cost of the utility as well as the availability of the resource. They showed that water supply tariffs must be reduced between 10 to 44 percent for lower consumers and raised between 3 to 106 percent for higher consumers in line with the availability of the water resource. While our study is unable to control for the cost of using water due to data availability, highlighting the importance of water use, pricing and financial sustainability provides key insights on the role of price and water use.

### **3. Methodology and data**

#### *3.1. Conceptual framework*

Conceptually, this study builds on the integrated social and economic household water model by Jorgensen et al. [47] to include the current COVID-19 crisis and handwashing behaviours. Previous studies suggest that demographics/socioeconomic factors, and household characteristics and composition (which include household size, land area, location, income, appliances and the presence of pool facilities) influence the consumption levels of water [48, 49, 50]. Another major determinant of water consumption is pricing. Renwick and Archibald [50] suggest that low-income households are more likely than higher-income households to respond to price increments. Similarly, Kenney et al. [51] show that price is an essential driver of residential water demand and additionally identify restrictions and climate/weather as contributing factors of water consumption. Past water use, habits, institutional and interpersonal trust, personal characteristics, such as social norms, behavioural control, attitudes and perceived risk of shortages can equally affect water use [52, 53, 54, 55, 56, 57]. Jorgensen et al. [47], in their integrated framework, discuss these factors based on the empirical model of Corral-Verdugo et al. [58].

In Figure 2, we modify the integrated framework of Jorgensen et al. [47] to reflect handwashing behaviours and individuals' level of concern about COVID-19. We hypothesize that an individual's level of concern about COVID-19 will positively impact handwashing, thereby increasing water use. Also, based on the theory of planned behaviour, social norms, attitudes, and perceived behavioural controls may further influence the perceptions and level of concern about COVID-19, which will affect the intention to engage in handwashing. However, these underlying behaviours will depend on exogenous factors, including the scarcity or availability of water. Given

that sub-Saharan Africa is not a water-sufficient region, it is likely that the ongoing handwashing campaigns across countries due to the COVID-19 pandemic may be impacted by insufficient access to clean water resources. Our proposed framework explicitly accounts for water scarcity, as depicted in Figure 2.

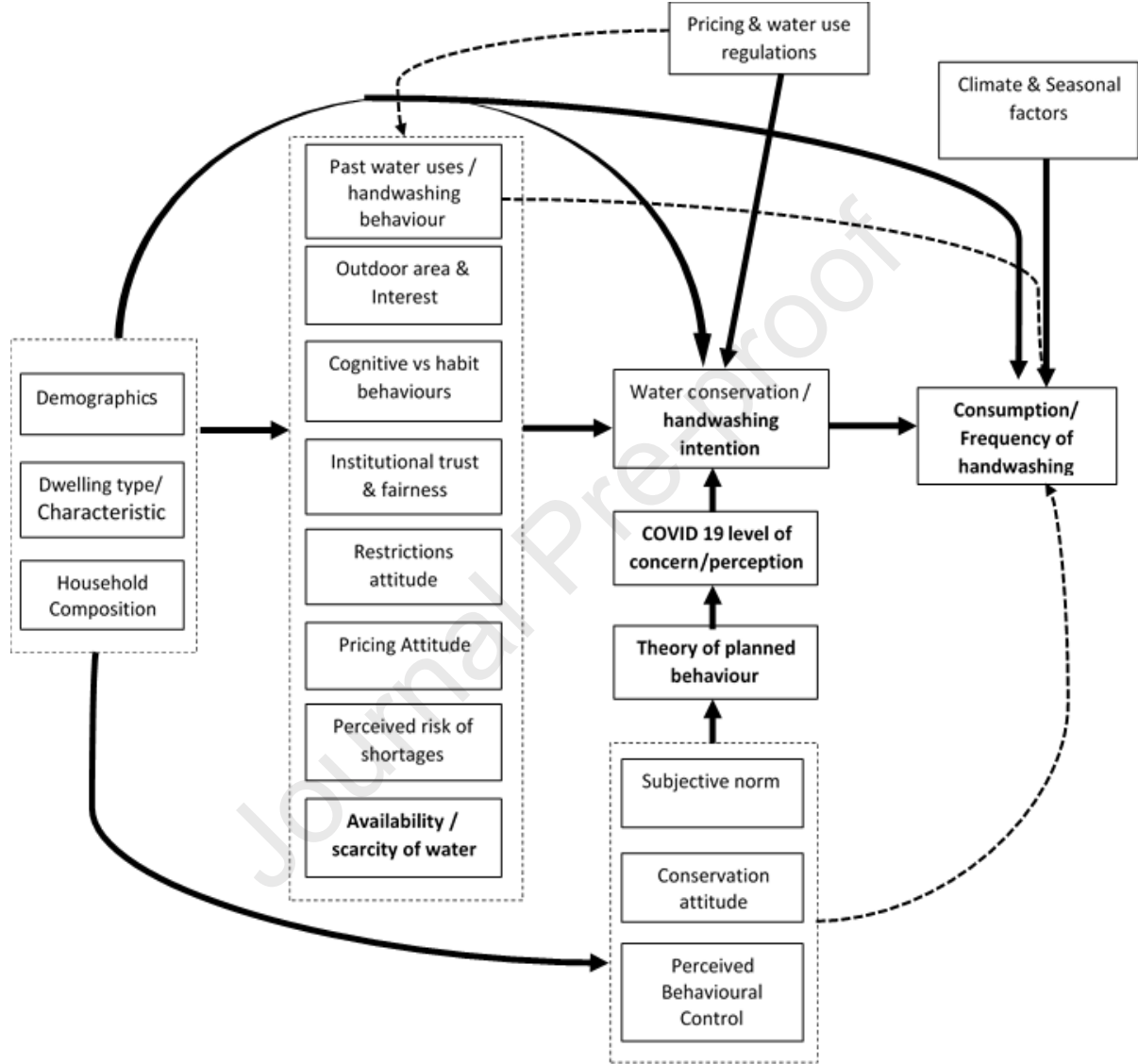


Figure 2: Extension to Jorgensen et al. [47] integrated social and economic household water consumption model.

### 3.2. Empirical estimation

Based on the reviewed literature and the conceptual framework discussed, we model the frequency of handwashing as a function of the level of concern about COVID-19, socioeconomic and demographic factors, and other control variables. Our outcome variable (that is, frequency per day

of handwashing under running water with soap for 20 seconds) is ordinal in nature (that is, 0 times, 1-2 times, 3-5 times and more than 5 times). The empirical model is specified in equation 1;

$$y_{ikjt}^* = \beta_0 + \beta_1 Covid\_Concern_{ikjt} + \mathbf{X}_{ikjt}\boldsymbol{\beta} + \mu_{kj} + \eta_j + \gamma_t + \varepsilon_{ikjt} \quad (1)$$

where the subscripts  $i, k, j$  and  $t$  represent the observation for each individual, community (administrative unit), country and survey wave, respectively; the outcome variable  $y^*$  is a latent variable ranging from 0 to  $\infty$ ; and *Covid\_Concern* is a variable capturing the individual's level of concern about the spread of COVID-19. On a scale of 1 to 5, with 1 being not concerned and 5 being very concerned, the individual is asked to indicate their level of concern about the spread of COVID-19 in their respective country. The vector  $\mathbf{X}_i$  represents socioeconomic and demographic factors, and other control variables, such as gender, age, water source (captured as whether water source is located inside house, inside compound or outside compound), locality (that is, urban-rural), administrative unit fixed effect ( $\mu_{kj}$ ), country fixed effect ( $\eta_j$ ) and survey wave fixed effect ( $\gamma_t$ ). The random error term is captured as  $\varepsilon_{ikjt}$ .

The observed response categories of frequency of handwashing are tied to the latent variable by the measurement model below;

$$y_{ikjt} = \begin{cases} 1 \Rightarrow 0 \text{ times} & \text{if } y_{ikjt}^* = 0 \\ 2 \Rightarrow 1 - 2 \text{ times} & \text{if } 0 < y_{ikjt}^* \leq 2 \\ 3 \Rightarrow 3 - 5 \text{ times} & \text{if } 2 < y_{ikjt}^* \leq 5 \\ 4 \Rightarrow 5 \text{ plus times} & \text{if } 5 < y_{ikjt}^* \leq \infty \end{cases}$$

From the expression above, the observed category,  $y_{ikjt}$ , changes value when the latent variable  $y^*$  crosses a threshold. Given the nature of the outcome variable, we estimate the empirical model using an extended ordered probit technique. The level of concern about COVID-19 spread is probably endogenous and this may bias our estimate if not accounted for. To resolve this potential problem, we applied the Principal Component Analysis (PCA) to generate a composite index from the individual's sources of information regarding COVID-19 (that is, newspapers, TV, radio, social media, friends/family, government messages and other), and this serves as an instrument for the level of concern about COVID-19. Based on the PCA, one component had eigen value strictly greater than one (see Table A1 in the appendix) and it explained about 30% of the variation in the indicators of sources of information regarding COVID-19. The oblique rotation of PC loadings in Table A2 (in the appendix) shows that the component consists of the following information sources: friends/family, government media, newspapers, social media and radio.

This component is used as instrument for level of concern about COVID-19. Consequently, we estimate an extended ordered probit model with an endogenous covariate<sup>2</sup>. The source of information regarding COVID-19 is likely to affect an individual's knowledge about COVID-19, hence influencing his/her concern about the spread of the virus. This implies that the sources of information about COVID-19 are important factors affecting an individual's level of concern about COVID-19 (thus, the relevance assumption is satisfied). Also, our instrument is likely to satisfy the exclusion restriction assumption since the source of information regarding COVID-19 can only affect the frequency of handwashing if one is concerned about the spread of COVID-19 and therefore adheres to the safety protocols such as washing of hands under running water with soap for at least 20 seconds to prevent infection. Thus, our composite indexes obtained from the sources of information are correlated with the level of concern about COVID-19 but uncorrelated with the frequency of handwashing. Our formal test as shown in "section 4: results and discussion" and Table A3 (in appendix) proves the validity of the instrument.

From existing data from the WHO, the distribution of COVID-19 infection and fatalities have some demographic dimensions. As a result, our study considers subsample analysis across gender and age-groups. Moreover, access to running water, which is an important element for frequent handwashing, differs across rural and urban areas, hence subsample analysis focusing on these areas is relevant. We further examine the heterogeneous effects of concerns about COVID-19 spread on the frequency of handwash across various water sources (that is, whether water is sourced from inside house, inside compound or outside compound). As COVID-19 responses and access to running water vary across countries, we expect the effect of the level of concern about COVID-19 on the frequency of handwashing to be heterogeneous. Thus, in addition to the pooled analysis, we provide country-specific analysis of the issue. Income level of individuals or households has the potential of affecting the individual's access to water. However, our dataset does not contain income levels, which makes it impossible for the authors to undertake income level analysis. That notwithstanding, we consider two variables from our dataset, which potentially could enable us learn about the economic status of individuals. These variables are; i) food worries due to lack of money or other resources, and ii) individual's concerns about economic impact of COVID-19. Thus, as food worries in this case is linked to lack of money or other resources, we deduce that those who are not worried about food, relatively have higher economic status than

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<sup>2</sup> We used the eoprobit command in STATA, which uses an instrument for the endogenous covariate (that is, level of concern about COVID-19 in our case).



those who are worried. Similarly, those who are not concerned about the economic impact of COVID-19 could be said to be economically (financially) stable or comfortable relative to those who are very concerned about the economic impact of the virus. Based on these two variables, we further investigate the heterogeneous effect of concerns about local spread of COVID-19 on the frequency of handwash across the following groups; a) food worries versus no food worries, and b) concerned about economic impact versus not concerned about economic impact of COVID-19.

The standard errors in our estimations are clustered at the primary administrative unit to account for possible correlation in the residual of the frequency of handwashing among individuals within the same community. By clustering the standard errors at the community level, we adjust the standard errors for inference, following Chiwona-Karlton et al. [59] based on their COVID-19 study. Access to water and water pricing may be similar for individuals living in the same community. However, our dataset does not have information on these and other relevant factors, which may affect the frequency of handwashing and could correlate among individuals. By controlling for primary administrative units (community level) fixed effect, we are able to account for water supply and water prices, which are normally homogeneous at community level.

### 3.3. *Data and sampling design*

The data for this study is based on an open-access survey designed and collected by GeoPoll<sup>3</sup>. Two rounds of the survey were administered through SMS and mobile web. The first round occurred between April 2<sup>nd</sup> and April 9<sup>th</sup>, 2020, and the second round from April 24<sup>th</sup> to May 8<sup>th</sup>, 2020. The data comprises of 12 sub-Saharan African countries: Benin, the Democratic Republic of Congo, Ghana, Ivory Coast, , Nigeria, Rwanda, South Africa, Kenya, Mozambique, Zambia, T-country and U-country<sup>4</sup>. The second round ran in all countries except for T-country and U-country. For the first round, a total sample of 4,788 was collected across the 12 countries in Africa, with each country having a sample of 400, except DRC, which had a sample size of 388. The second round had a sample size of 3994, with 400 from each country, with the exception of Rwanda, which had a sample size of 394. These sample sizes give a 5% margin of error and a 95%

<sup>3</sup> GeoPoll dataset can be accessed from <https://data.humdata.org/dataset/covid-19-impacts-africa> . The survey instrument can also be obtained from the same website. The dataset for both waves was directly requested from GeoPoll.

<sup>4</sup> GeoPoll insists on making T-country and U-country anonymous. This is because the authorities from these countries did not give GeoPoll permission to carryout country level analysis based on data from these countries. Interested readers can contact the authors for the identification of these countries.



confidence interval for each round. A simple random sampling technique was used by GeoPoll to select respondents from their database, which consists of a list of mobile subscribers in each country surveyed. The sample is made up of literate adults with access to mobile phones, hence reaching relatively wealthier population. The sample was roughly nationally representative by age, gender and location. The survey was administered in English, French, Portuguese, Swahili, and Kinyarwanda, depending on country.

Table 1 shows descriptive statistics for the variables of interest for this study. About 54.6% of the sample were washing their hands for 20 seconds more than 5 times a day prior to the survey; however, 4.2% did not wash their hands for 20 seconds during the same period. Among individuals who wash their hands for more than 5 times a day for at least 20 seconds under running water with soap, South Africa has the highest proportion of individuals (that is, 65.1%), while Ivory Coast has the least (that is, 45.5%). However, among those who do not wash their hands under running water with soap for at least 20 seconds, Mozambique recorded the highest rate of 7.1%, followed by Ivory Coast (6%) with Ghana recording the lowest rate of 1.9%. About 39.4% of respondents indicated that they sourced water outside their compound, 31.3% sourced water from inside their house and about 29.3% sourced water from inside their compound<sup>5</sup>.

From Table 1, South Africa is the country with the highest access to basic drinking water with a rate of 93.9%, followed by Ghana with a rate of 85.8%. The country with the least rate of access to basic drinking water is Democratic Republic of Congo (46%). WHO/UNICEF defines basic drinking water services to comprise of drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip. These improved water sources according to WHO/UNICEF are piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water<sup>6</sup>. In the case of access to handwashing facility with soap and water, the countries have rates less than 50%. Rwanda has the least rate of access to handwashing facility with soap and water, with a rate of 4.6%. According to the World Bank's World Development Indicators, handwashing facilities may be fixed or mobile and include a sink with tap water, buckets with taps, tippy-taps, and jugs or basins designated for handwashing. And soap includes bar soap, liquid soap, powder detergent, and soapy water but does not include ash,

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<sup>5</sup> It should be noted that the question on sources of water was only asked in the first wave of the survey. Also, the questionnaire in South Africa did not include questions on water sources in both waves. Since not all respondents in the first wave responded in the second wave and new respondents were included in the second wave, we restrict the descriptive statistics for water sources on the data from the first wave.

<sup>6</sup> World Development Indicators, <https://databank.worldbank.org/source/world-development-indicators>

soil, sand or other handwashing agents. Thus, the WHO/UNICEF defines a basic handwashing facility as a device to contain, transport or regulate the flow of water to facilitate handwashing with soap and water in the household<sup>7</sup>.

Generally, the level of concern about the spread of COVID-19 is relatively high, with an average score of about 4.26. The country with the highest score of concern about the local spread of COVID-19 during the periods of the survey is South Africa (with a score of 4.59 ), followed by Ghana (with a score of 4.57). However, during the same period, Democratic Republic of Congo scored the lowest rate on concern about the local spread of COVID-19, having a score of 3.35. The sample comprises of about 45% females, and 67% of the total sample live in urban areas. The age of respondents ranges from 15 to 91 years with an average age of about 31 years. The majority of individuals (that is, 71%) are aged between 15 and 35 years, and only 1.4% of the sample are aged 60 years and above.

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<sup>7</sup> World Development Indicators, <https://databank.worldbank.org/source/world-development-indicators>

Table 1: Descriptive statistics

	All		Benin	DR. Congo	Ghana	Ivory Coast	Kenya	Mozambique	Nigeria	Rwanda	South Africa	T- country	U- country	Zambia
Variable	Mean	SD	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Female	0.447	0.497	0.445	0.373	0.48	0.412	0.414	0.51	0.503	0.455	0.50	0.50	0.498	0.325
Urban	0.669	0.471	0.644	0.731	0.685	0.756	0.54	0.716	0.824	0.407	0.653	0.675	0.525	0.801
Level of concern COVID	4.259	1.367	3.98	3.353	4.571	4.013	4.494	4.561	4.51	4.273	4.588	3.703	4.373	4.459
Age	30.83	9.907	29.9	31.72	31.23	29.45	29.87	30.58	32.34	28.55	35.99	29.81	31.40	28.84
<i>Handwashing frequency (%)</i>														
0 times	4.2		5.0	4.8	1.9	6.0	2.4	7.1	2.8	3.8	2.5	4.5	4.5	5.5
1-2 times	13.8		14.1	16.9	10.4	17.6	9.0	22.8	12.6	9.3	7.4	21.0	13.0	14.5
3-5 times	27.4		33.3	21.1	36.9	30.9	23.0	21.9	32.0	26.4	25.0	26.8	20.3	27.4
More than 5 times	54.6		47.6	57.2	50.9	45.5	65.6	48.3	52.6	60.5	65.1	47.8	62.2	52.6
<i>Water sources (%)</i>														
Inside compound	29.3		11.3	31.7	29.0	36.0	40.7	21.5	37.0	27.0	xxx	29.3	23.0	36.0
Inside house	31.3		67.5	10.1	37.5	51.7	22.5	40.7	34.5	3.5	xxx	26.7	9.5	39.8
Outside compound	39.4		21.2	58.2	33.5	12.3	36.8	37.8	28.5	69.5	xxx	44.0	67.5	24.2
<i>Age groupings (%)</i>														
Age=<35	71.15		71.63	66.37	67.5	78.9	76.5	69.3	63.7	81.2	52.3	77.5	67.5	82.8
35<Age<60	27.45		26.25	31.22	31.13	21.0	23.1	29.7	35.3	18.3	42.7	22.5	30.7	16.6
Age>=60	1.4		2.12	2.41	1.38	0.1	0.4	1.0	1.0	0.5	5.0	0.0	1.8	0.6
<i>Access to basic drinking water (%)*</i>														
			65.4	46.0	85.8	70.9	61.6	63.4	77.6	60.4	93.9	60.7	55.9	65.4
<i>Access to HSWS (%)*</i>														
			12.0	19.2	41.5	21.6	26.8	xxx	33.2	4.6	44.4	48.4	22.6	17.9

Source: Authors' own construction from GeoPoll data, except (\*) which are sourced from the World Bank's World Development Indicators, we used 2020 values.

NB: Access to basic drinking water and access to basic handwashing facilities including soap and water (HSWS), respectively, represent the proportion of the population with access to at least basic drinking water and basic handwashing facilities including soap and water (HSWS). SD represents standard deviation. GeoPoll insists on making T-country and U-country anonymous, because the authorities from these countries did not give GeoPoll permission to carryout country level analysis based on data from these countries. Interested readers can contact the authors for the identification of these countries. "xxx" implies no information.

#### 4. Results and discussions

In Table 2, we estimate ordered probit models with and without an endogenous covariate. In each case, we estimate the model with and without country fixed effect. However, we controlled for survey wave and primary administrative unit fixed effects in all the models. In columns 3 and 6 of Table 2, we controlled for individual's source of water. This results to a drop in the number of observation from 8,782 to 6,816, due to the fact that the question on sources of water was only asked in the first wave of the survey and not all respondents were in both waves. Also, the questionnaire for South Africa did not include questions on water sources in both waves. Thus, the number of observation of 6,816 comprises of 4,388 respondents from the first wave, and 2,428 of respondents from the first wave who also responded in the second wave. As stated earlier, the level of concern about COVID-19 is treated as endogenous and we use the derived composite index based on the individual's sources of information as an instrument. From the extended ordered probit model with endogenous covariate, the composite index (that is, Comp1), which serve as instrumental variable for the level of concern about COVID-19, significantly explain the endogenous variable (see Table A3 in the appendix). This satisfies the relevance assumption. In addition, there exists a significant correlation between the error term of the structural model (that is, handwashing model) and the error term of the model of the level of concern about COVID-19. This indicates that the variable representing the level of concern about COVID-19 is indeed an endogenous covariate, and, as we account for the endogeneity, our estimate for the level of concern about COVID-19 approaches its true estimate. Furthermore, the Cragg-Donald F-statistics and the Hansen J-statistics for overidentification show that our instrument is valid.

Columns (1) to (3) of Table 2 do not address the problem of endogeneity associated with the level of concern about COVID-19, whereas columns (4) to (6) do. From all the models, the frequency of handwashing is significantly explained by age, level of concern about COVID-19, gender and source of water in models in columns (3) and (6). Our models of interest are column 5 and 6, which accounts for primary administrative unit, country and wave fixed effects, and also the endogeneity of the level of concern about COVID-19. The results show that the frequency of handwashing increases with the level of concern about COVID-19. That is, as the level of concern about the spread of COVID-19 increases, individuals tend to increase the number of times they wash their hands under running water for at least 20 seconds, as prescribed by WHO as a way of reducing infection. This corroborates the assertion by Borghi, Guinness & Curtis [15] and Mackert, Liang & Champlin [16] that handwashing is used to prevent the spread of infections and diseases.

The results also support the theory of planned behaviour, which suggests that intention (influenced by attitudes, subjective norms and perceived behavioural controls) is a significant driver of behaviour, which in our case is handwashing [26]. Moreover, the results are consistent with those of Curtis et al. [30], who, based on a review of eleven countries (with six from Africa), found that education and fear during occasional outbreaks of epidemics like cholera encourage handwashing. Furthermore, the findings corroborate that of Shook et al. [35] who relate individual's germ aversion and pathogen disgust sensitivity (that is, concern for COVID-19) to willingness to engage in disease prevention behaviours. Also, Thorpe et al. [39] stipulate that handwashing behaviour of individuals is associated with individuals health anxiety and their compulsion levels to wash their hands.

Table 2: Handwashing ordered probit model

VARIABLES	(1) Oprobit	(2) Oprobit	(3) Oprobit	(4) eoprobit	(5) eoprobit	(6) eoprobit
Age	0.0246*** (0.0080)	0.0246*** (0.0080)	0.0289*** (0.0093)	0.0209*** (0.0073)	0.0208*** (0.0072)	0.0246*** (0.0085)
Age squared	-0.0002** (0.0001)	-0.0002** (0.0001)	-0.0003** (0.0001)	-0.0002** (0.0001)	-0.0002** (0.0001)	-0.0003** (0.0001)
COVID-19 Concern	0.0872*** (0.0123)	0.0875*** (0.0124)	0.0825*** (0.0137)	0.3975*** (0.0609)	0.4062*** (0.0608)	0.3890*** (0.0744)
Female	0.2259*** (0.0336)	0.2250*** (0.0336)	0.2038*** (0.0434)	0.2105*** (0.0312)	0.2092*** (0.0311)	0.1925*** (0.0404)
Urban	0.0454 (0.0324)	0.0469 (0.0326)	0.0381 (0.0365)	0.0299 (0.0293)	0.0313 (0.0292)	0.0248 (0.0329)
<i>Water source (ref: inside the compound)</i>						
Inside house			0.0660 (0.0440)			0.0578 (0.0388)
Outside compound			-0.0813* (0.0444)			-0.0680* (0.0400)
Observations	8,782	8,782	6,816	8,782	8,782	6,816
Administrative FE	YES	YES	YES	YES	YES	YES
Country FE	NO	YES	YES	NO	YES	YES
Wave FE	YES	YES	YES	YES	YES	YES
Pseudo R2	0.0350	0.0351	0.0369			
Cragg-Donald F stat <sup>A</sup>				22.78	21.95	19.05
Hansen J statistic (p-value) <sup>A</sup>				0.439	0.370	0.326

Robust standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. The outcome variable is the frequency of handwashing in the form of an ordinal variable. Models are stepwise estimated by either controlling or not controlling for country fixed effect. We controlled for administrative unit and wave fixed effect in all the models. Models (1) -(3) are estimated using an ordered probit technique and (4) -(6) are based on extended ordered probit technique with endogenous covariate. Standard errors are clustered at primary administrative unit. Note: (A) in models 4 - 6, we used ivreg28 in stata to compute the Cragg-Donald F-stat and Hansen J stat since there is no formal test for overidentification for the extended ordered probit model with endogenous covariate in Stata..

Table 3 presents the marginal effect based on our estimation. It shows the marginal change in the probability of the outcome (that is, frequency of handwashing: 0 times, 1-2 times, 3-5 times and more than 5 times) resulting from marginal change of each covariate. We find that a marginal increase in the level of concern about the spread of COVID-19 decreases the probability of individuals not washing their hands with soap under running water for 20 seconds. It also decreases the probability of individuals washing their hands 1-2 times and 3-5 times. However, it increases the probability of them washing their hands more than 5 times due to the concern about the spread of COVID-19. The probability of frequency of handwashing 0 times, 1-2 times, 3-5 times and more than 5 times changes on the order of -0.007 (-0.008), -0.014, -0.011 (-0.010) and 0.033 (0.031), respectively, with a marginal increase in level of concern about the spread of COVID-19. It should be noted that across all categories of frequency of handwashing, the average marginal effects must sum to zero. This is because any increase in the probability of one category must be offset by a decrease in another category. From the descriptive statistics in Table 1, it should be recalled that the proportion of individuals washing their hands more than 5 times is relatively more than the other groups, hence the marginal change for washing hands for more than 5 times is expected to be relatively higher. This explains the negative marginal effect for those not washing their hands, washing hands for 1-2 times and 3-5 times.

In the case of age, we find a non-linear relationship between age and the frequency of handwashing (see Table 2). Thus, the frequency of handwashing increases with age and later reduces after a certain threshold (that is, about 52 years, based on the model with all the sample). It should be noted that this quadratic relationship is between age and frequency of handwashing, and concern about local spread of COVID-19 has no bearing on this relationship. The marginal effect evaluated at the sample mean suggests that a marginal increase in age decreases the probability of not washing hands and of washing hands 1-2 times and 3-5 times, but increases the probability of handwashing more than 5 times (see Table 3).

In the case of gender, the results show a significant difference between females and males in the frequency of handwashing. Females wash their hands relatively more frequently than males (see Table 2). From the marginal effect estimation in Table 3, a change from male to female decreases the probability of not washing hands, or washing hands 1-2 times and 3-5 times, but increases the probability of handwashing more than 5 times. In most developing countries, women and girls are responsible for collecting water and are the main users and managers of water, as they are mainly responsible for cooking, laundry and other household chores like fetching water [60]. Moreover,

women are responsible for enforcing hygienic practices in home environments. This may explain why females frequently wash their hands relative to males.

Our results show a statistically significant effect of source of water on frequency of handwash. From Table 2, individuals who source water from outside their compound are less likely to wash this hands under running water with soap for at least 20 seconds, relative to those who source water from inside their compound. The marginal effect from Table 3 shows that an individual changing his/her water source from inside compound to outside compound increases the probability of not washing hands, or washing hands 1-2 times and 3-5 times, but decreases the probability of handwashing more than 5 times. Similar result is found when an individual changes his/her water source from inside house to outside compound, however, the marginal effect is relatively higher in this case.

Table 3: Marginal effect

VARIABLES	(1) 0 times	(2) 1-2 times	(3) 3-5 times	(4) More than 5 times
<i>Water source not controlled in model</i>				
Age	-0.001***	-0.002***	-0.001***	0.004***
COVID-19 Concern	-0.007***	-0.014***	-0.011***	0.033***
Female vs Male	-0.019***	-0.037***	-0.029***	0.085 ***
Urban vs Rural	-0.004	-0.008	-0.006	-0.018
<i>Water source controlled in model</i>				
Age	-0.001***	-0.002***	-0.001***	0.004***
COVID-19 Concern	-0.008***	-0.014***	-0.010***	0.031***
Female vs Male	-0.018***	-0.034***	-0.025***	0.077***
Urban vs Rural	-0.004	-0.006	-0.005	0.014
<i>Source of water</i>				
Inside house vs inside compound	-0.006	-0.011	-0.008	0.025
Outside compound vs inside compound	0.008*	0.014*	0.009*	-0.031*
Outside compound vs inside house	0.013***	0.024***	0.018***	-0.055***

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

#### *Heterogeneous effect of level of concern about COVID-19 on frequency of handwashing*

COVID-19 infections and fatalities have demographic dimensions varying across gender and age groups. As a result, we estimate the model for different gender and age groups, and also based on locality (that is, urban/rural), source of water and economic status. From Table 4 and Table 5, we find a significant effect of level of concern about the spread of COVID-19 on the frequency of handwashing across all categories (except, those sourcing water from inside their house), with variability in the magnitude of the effects. For gender, we observed this effect is higher for females relative to males. However, there is no statistically significant difference between effect for males and



females as shown by the Hausman's test. There is therefore more potential for both males and females to increase their hand washing due to COVID-19 concerns.

The age group analysis shows that the effect of the level of concern about the spread of COVID-19 on the frequency of handwashing increases with higher age cohort. Thus, as those in older age group tend to be more concern about the local spread of COVID-19 they are likely to follow the preventive protocol of handwashing. Because old age is associated with the severity and mortality of patients with COVID-19 [61], and most older individuals have underlying health conditions, especially in sub-Saharan Africa, they tend to be more concerned about the spread of the virus (this is observed from our data). Given their relatively high risk level, it is reassuring to see that older individuals tend to adhere more to the protocols prescribed by health authorities in preventing infections from COVID-19, hence washing their hands more frequently with soap under running water for at least 20 seconds.

Although the level of concern about the spread of COVID-19 increases the frequency of handwashing in both rural and urban areas, surprisingly, the effect is relatively higher in rural areas. This could be due to several reasons. First, the frequent washing of hands may be seen as a critical preventive measure for COVID-19 in rural areas, where they mostly either lack or have deficient health infrastructure. Currently, most treatment centres in sub-Saharan Africa are located in urban areas. Second, the poor economic status of most rural residents could make it more challenging if not impossible to acquire protective equipment, such as hand sanitisers, face masks and personal protective equipment. In China, a survey conducted in January 2020 revealed that about 63.3% of rural communities either could not buy face masks or had difficulty in buying face masks [62, 63].

The sub-sample analysis based on individuals' water sources shows that an increase in the concern about the local spread of COVID-19 increases the probability of handwashing in the case of those who sourced water from inside or outside their compound (see Table 5). Although the effect is higher for those who source water from inside compound than for those sourcing water from outside compound, we find no statistically significant difference between the two. Also, we investigate the association between concern about local spread of COVID-19 and frequency of handwashing for those who are worried (or not worried) about food due to lack of money or other resources. Our results show positive association between concern about local spread of COVID-19 and frequency of handwash for both those who are worried about food due to lack of money or other resources and those who are not worried (see Table 5). Although the effect is higher for



those who are worried about food relative to those not worried, the difference between the two groups is not statistically significant. Similarly, we find significant positive correlation between concern about local spread of COVID-19 and frequency of handwashing, for individuals who are not concern about the economic impact of COVID-19 and those who are very concerned about the economic impact. The effect of concern about the local spread of COVID-19 on frequency of handwashing is higher for those who are very concerned about the COVID-19 than those who are not concern about economic impact, albeit insignificant statistical difference between the two groups.

#### *Country-specific analysis*

Given that COVID-19 infection and fatality rates, government response, and access to water differ across countries, we examined the effect of the level of concern about the spread of COVID-19 on the frequency of handwashing for each of the 12 sub-Saharan African countries in this study. The results of the ordered probit estimation are shown in Table 6. With the exception of Democratic Republic of Congo, Nigeria, Mozambique, T-country and U-country, we find that frequency of handwashing with soap under running water for at least 20 seconds increases with an increase in the level of concern about the spread of COVID-19 for all the other countries under study. This suggests that individuals in these countries, in an attempt to prevent infection, tend to follow the prescribed protocol of frequent handwashing with soap under running water. For all the countries with significant impact of level of concern of COVID-19 on handwashing, the marginal effect estimation in Table 7 shows that an increase in the level of concern about the spread of COVID-19 decreases the probability of not washing hands, and washing hands 1-2 times and 3-5 times, but increases the probability of handwashing more than 5 times. However, there is variation of the impact across countries. As mentioned earlier, the average marginal effects across all categories must sum to zero. This is because any increase in the probability of one category must be offset by a decrease in another category. From Table 7, the increase in the probability of handwashing more than 5 times resulting from an increase in the level of concern about COVID-19, for example, ranges from 3% for Benin to 6.3% for South Africa.

Table 4: Extended ordered probit model with endogenous covariate: Heterogeneous effect

VARIABLES	(1) Female	(2) Male	(3) Rural	(4) Urban	(5) Age=<35	(6) 35<Age<60	(7) Age>=45 <sup>A</sup>
Covid-19 Concern	0.4221*** (0.1051)	0.379*** (0.0826)	0.460*** (0.127)	0.377*** (0.0671)	0.375*** (0.0790)	0.461*** (0.131)	0.737*** (0.0590)
Observations	3,925	4,857	2,908	5,874	6,248	2,411	823
Administrative FE	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES	YES	YES	YES
Hausman's test, chi2	9.64		43.45*				

Robust standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. The outcome variable is the frequency of handwashing in the form of an ordinal variable. Models are estimated by extended ordered probit with endogenous covariate. We controlled for age, age squared and locality in the gender models. For the locality models, we controlled for gender, age and age squared. The age-group models controlled for gender and locality. In all the models, we account for country, administrative unit and wave fixed effect. Standard errors are clustered at primary administrative unit. (A) the model could not converge for sub-sample above 60 and also above 50.

Table 5: Extended ordered probit model with endogenous covariate: Heterogeneous effect (water sources &amp; economic)

VARIABLES	Source of water			Food worries due to lack of money or other resources		Concern about economic impact of Covid-19	
	(1) Outside compound	(2) Inside compound	(3) Inside house	(4) Not worried	(5) Worried	(6) Not much concerned	(7) Very concerned
Covid-19 Concern	0.3224** (0.1429)	0.4800*** (0.1285)	0.2350 (0.1770)	0.3673*** (0.1081)	0.4471*** (0.0824)	0.3408*** (0.0664)	0.5617*** (0.1211)
Observations	2,595	2,019	2,202	1,730	7,052	2,570	6,212
Administrative FE	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES	YES	YES	YES
Hausman's test, chi2	0.00		1.41		0.00		

Robust standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. The outcome variable is the frequency of handwashing in the form of an ordinal variable. Models are estimated by extended ordered probit with endogenous covariate. We controlled for age, age squared, gender, locality, country, administrative unit and wave fixed effect. Standard errors are clustered at primary administrative unit.

Table 6: Country specific estimation

VARIABLES	(1) Benin	(2) DR. Congo	(3) Ghana	(4) Ivory Coast	(5) Kenya	(6) Mozamb ique	(7) Nigeria	(8) Rwanda	(9) South Africa	(10) T-country	(11) U- country	(12) Zambia
Covid-19 Concern	0.077** (0.032)	0.040 (0.025)	0.146** (0.059)	0.094*** (0.030)	0.101* (0.055)	0.043 (0.027)	0.073 (0.052)	0.115*** (0.038)	0.182*** (0.044)	0.032 (0.033)	0.074 (0.051)	0.152*** (0.040)
Observations	800	788	800	800	800	800	800	794	800	400	400	800
Administrative FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Wave FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	YES

Robust standard errors in parentheses \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . The outcome variable is the frequency of handwashing in the form of an ordinal variable. We controlled for wave fixed effect in all the models, except T-country and U-country models, which had only one wave. In all models, we controlled for age, age squared, gender, locality (urban dummy) and administrative unit fixed effect. Due to convergence issues, we estimated all models by an ordered probit technique. Standard errors are clustered at primary administrative unit.

Table 7: Marginal effect of level of concern about COVID-19 by country

VARIABLES	(1) 0 times	(2) 1-2 times	(3) 3-5 times	(4) More than 5 times
Benin	-0.008	-0.013	-0.009	0.030
Ghana	-0.007	-0.021	-0.027	0.055
Ivory Coast	-0.011	-0.017	-0.008	0.035
Kenya	-0.005	-0.013	-0.016	0.033
Rwanda	-0.009	-0.015	-0.019	0.043
South Africa	-0.010	-0.020	-0.034	0.063
Zambia	-0.016	-0.025	-0.017	0.058

Columns (1) to (4) are the marginal effect of level of concern about COVID-19 on frequency of handwashing based on the estimations in Table 6. The marginal effect is calculated only for countries with statistically significant effects.

*Implications of our findings for water-scarce environment*

From the results, as the level of concern about COVID-19 rises, the likelihood for people to wash their hands multiple times increases. With no sign of decline in COVID-19, our first important deduction is that water usage should be increasing to sustain the practice of handwashing. However, there are two perennial problems with water supply in sub-Saharan Africa that might constraint efforts to sustain the practice of handwashing. They include water affordability and access. In fact, the United Nations' Sustainable Development Goal target 6.1 aims for universal access and equitable access to safe and affordable water for everyone by 2030. This implies that sustaining efforts to promote the practice of handwashing will require actions on water cost and investment. According to the United Nations and Water Supply and Sanitation Collaborative Council, cost for water and sanitation services for households should not exceed 5 percent of their income. However, in sub-Saharan Africa, the cost of water takes a significant portion of household income. A study by Shack/Slum Dwellers International [SDI] [64] compute the cost of water as a percent of household income for four cities in sub-Saharan Africa: Blantyre, Dar es Salaam (Tanzania), Harare (Zimbabwe) and Windhoek (Namibia). For piped water only, the cost of municipal supply of water for six-person household that consumes 50 liters per person per day ranges from 11% to a theoretical 112% of household income [64].

A more recent global survey in 2019 on global value of water consisting of 44 cities in Africa, showed a modest increase in tariff of 1.9% and average water tariff of US\$1.16/m<sup>3</sup> [65]. However, wide disparity was noticed among cities in Africa. While Harare (Zimbabwe) and Cape Town (South Africa) experienced 62% and 49% decline in water tariff in 2019, respectively, in Kigali (Rwanda), Lome (Togo), Durban (South Africa), Pretoria (South Africa), Windhoek (Namibia), Johannesburg (South Africa), and Accra (Ghana), water tariffs went up by 77.1%, 19%, 14%, 10%, 9.9%, 9.9% and 8%, respectively. In terms of highest and lowest tariff countries, water price in Addis Ababa (Ethiopia) was the lowest (US\$0.13/m<sup>3</sup>) but highest in Praia [Cabo Verde] (US\$5.17/m<sup>3</sup>) followed by Mbabane [Eswatini] (US\$4.79/m<sup>3</sup>). One effective course of action may be for governments in Africa to implement well-thought through cross-subsidies particularly for low-income households to enable them access water.

To ensure that water is affordable to all, some governments in Africa at the peak of the pandemic have provided subsidies on water utility. For example, the government of Ghana absorbed all water bills for all Ghanaians from April 2020 to January 2021 [66]. For households with no home connection to water, the government supplied water to their homes. Also, the government of Ivory

Coast paid all water bills for 1 million low-income households in April and May 2019. Furthermore, the government of South Africa during the period of the lockdown established hotline support for areas in need of water. While these interventions by various governments during the pandemic were critical, for long-term promotion of handwashing practices, which are critical for preventing future pandemics, a sustainable subsidy programme that would ease the water expenditure burden of consumers is required.

Second, though we found the level of concern about COVID-19 raises the likelihood of a person washing his/her hands frequently, limited access and the severe water scarcity in sub-Saharan Africa could be an important constraint to sustain the practice, especially among very vulnerable groups, such as the old, rural populations and women. As shown in Table 1, an average of 67.25% of the population in these countries have access to at least basic drinking water and an average of 26.56% of the population have access to basic handwashing facilities including soap and water. A simple correlation test between the marginal effect of handwashing for at least 5-times (see Table 7) and access to water shows a positive statistically significant value of 0.68, implying that an increase in access to water has the potential to increase the frequency of handwashing which is a preventive measure to most viral infection. A key problem that makes it difficult for utilities in Africa to improve coverage and access involves underinvestment in infrastructure and lack of maintenance for aging infrastructure. Improving the financial stance of the utilities may prove critical to improve water coverage. However, in Africa, a recent World Bank report [67] indicate that the link between enhanced financial performance and water coverage is only strong for some group of utilities but when it comes to smaller utilities it is very weak, which means such utilities may have to depend on external funds to promote coverage. In this regard, providing government support especially to small utilities in low-income countries could be critical to improving water coverage.

Running a successful subsidy programme to reduce price burden and promote investment in water infrastructure could go a long way to help improve affordability and access. However, scarcity in water, could be naturally imposed. Poor rains could create acute water supply shortages, with obvious implications for water price inflation. This implies that in addition having a sustainable subsidy programme to promote affordability and access, governments in Africa should run parallel programmes to promote water use efficiency in the region. For example, although South Africa has relatively higher access to basic drinking water (about 94%) and handwashing facilities (that is, 44%), the country has been faced with a water crisis in the recent past (2017-2018), the country

resorted to water-saving management campaigns as a strategy to manage the water crisis of 2017/2018 [68]. Adopting such a tripartite programme could help sustain the efforts of handwashing, with obvious future implications for managing similar pandemics in the future and other communicable diseases such as Cholera.

## 5. Conclusion

This study uses a unique dataset from 12 sub-Saharan African countries to investigate the effect of the level of concern about the spread of COVID-19 on the frequency of handwashing with soap under running water for a minimum of 20 seconds. Because the infection and fatality rates of COVID-19 have demographic dimensions, we also considered gender- and age-group, locality and various water sources analysis. We found that the level of concern about the spread of COVID-19 significantly increases the frequency of handwashing more than 5 times a day. We observed that, on a normal day, females typically wash their hands more frequently than males; however, of the concern about the spread of COVID-19, no statistically significant difference between females and males was found. The effect of the level of concern about the spread of COVID-19 on frequency of handwashing is high for older individuals. This could be attributed to the fact that fatalities caused by COVID-19 are mostly centered in older age groups who are most likely to suffer from underlying medical conditions. The country-specific analysis shows a significant effect of concern about the spread of COVID-19 on frequency of handwashing for seven out of the twelve countries. COVID-19 concerns make individuals in these countries more likely to wash their hands with soap under running water for a minimum of 20 seconds more than 5 times a day, with a probability ranging from 3% for Benin to 6.3% for South Africa.

From the above, we expect that the continuous rise in cases of COVID-19 will increase concerns among people, and this is projected to impact the number of times people wash their hands with consequences on water usage. However, already, there are concerns about water shortage in Africa, a situation which suggests that Africa countries improve the reliability of water supply by expanding infrastructure and promoting water use efficiency among its citizenry. Thus, without proper water use management and investment in water infrastructure, the act of frequent handwashing might be constraint and cause the spread of the virus to increase. The situation in sub-Saharan Africa calls for urgent and effective water management and supply strategies in the region. The current rate of water consumption suggests that water resource may be a scarce commodity in the future if relevant authorities fail to take action. Efforts must gear towards

protecting the resource and popularizing its prudent use. This will ensure an appropriate attitude from users and management and lead to the conservation of the resource. In addition, proper skills in managing water systems' finances will be important for prudent use of generated revenues, conducting frequent maintenance of the system, and productivity improvement.

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## Appendix

Table A1: Eigenvalues from principal component analysis

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.107	1.092	0.301	0.301
Comp2	1.015	0.031	0.145	0.446
Comp3	0.983	0.054	0.140	0.586
Comp4	0.929	0.180	0.133	0.719
Comp5	0.749	0.094	0.107	0.826
Comp6	0.655	0.093	0.094	0.920
Comp7	0.562		0.080	1.000
Kaiser-Meyer-Olkin (KMO)				0.7094
Bartlett test of sphericity (Chi2)				5662.6***

Table A2: PC loadings for exploratory component analysis with oblique rotation

Variable	Comp1	Unexplained
Friends/family	<b>0.514</b>	0.442
Government media	<b>0.443</b>	0.586
Newspapers	<b>0.487</b>	0.50
Othermedia	0.095	0.981
Radio	<b>0.306</b>	0.803
SocialMedia	<b>0.345</b>	0.749
TV	0.282	0.833

Note: Factor loadings >0.30 in bold

Table A3: Full results from extended ordered probit regression with endogenous covariate

VARIABLES	(1) Handwashing	(2) Covid concern
Age	0.0208*** (0.0072)	
Age squared	-0.0002** (0.0001)	
Female	0.2092*** (0.0311)	
Urban	0.0313 (0.0292)	
Covid concern	0.4062*** (0.0608)	
Comp1		0.0810*** (0.0120)
Media consumption (ref: consuming less)		
Consuming more		0.2559*** (0.0518)
No change in consumption		0.0969** (0.0494)
Constant		4.0737***
/Handwashing		(0.0638)
cut1	0.2286 (0.3623)	
cut2	0.9932** (0.3279)	
cut3	1.746*** (0.2983)	
var(e. Covid concern)		1.8422*** (0.1019)
corr(e. Covid concern,e.Handwashing)		-0.4494*** (0.0827)
Observations	8,782	8,782
Administrative FE	YES	YES
Country FE	YES	YES
Wave FE	YES	YES

Robust standard errors in parentheses \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

The outcome variable is the frequency of handwashing in the form of an ordinal variable. The model is estimated using an extended ordered probit technique with an endogenous covariate (where level of concern about COVID 19 is endogenous). The principal component (Comp1), derived from the sources of information about COVID 19, is used as an instrument for the variable representing level of concern about COVID 19. We controlled for administrative unit, country and wave fixed effect in the model. Standard errors are clustered at primary administrative unit.

## CRediT author statement

**Franklin Amuakwa-Mensah:** Conceptualization of idea, Methodology, Estimation, Data curation, Writing- Original draft preparation, Revision of manuscript- writing

**Rebecca Afua Klege:** Conceptualization of idea, Writing- Original draft preparation, Result discussion, Revision of manuscript-writing, review & editing

**Philip Kofi Adom:** Conceptualization of idea, Writing- Original draft preparation, Result discussion, Revision of manuscript-writing, review & editing

**Gunnar Köhlin:** Conceptualization of idea, Writing- Original draft preparation, Result discussion, review & editing

**Declaration of interests**

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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